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# A Probe Sampling Method for Country Elevators

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## ABSTRACT

A method for using mechanical probes to sample trucks and wagons was developed. The plan involves the collection of multiple samples, with none taken from the center or corners of loads. In tests at a country elevator, the plan yielded accurate corn and soybean samples relative to the pelican method and reduced variability by 15 to 25% in Official Grade factors.

## INTRODUCTION

For both trading and management decisions, grain quality is determined from tests on a sample. In country elevator trading, samples account for about  $2 \times 10^{-4}$  of the grain mass, a tiny fraction to be representative of the entire lot. Although sampling procedures for official grading under the United States Grades and Standards have been established by regulation, sampling practices for house-grade inspections (e.g., at country elevators) are established by individual firms. Speed and cost are considered, as well as accuracy.

The country elevator faces at least three sampling constraints that are not present in an official Federal Grain Inspection Service (FGIS) inspection.

1. Limited time to sample, normally 30 to 60 s, while the grain is being weighed.
2. Widely varying quality requiring the elevator to know quality before the load is dumped.
3. Varying load size, from less than 3.0 m<sup>3</sup> (100 bu) to more than 36.5 m<sup>3</sup> (1200 bu) per load. Testing in the scale house limits the volume of sample that can be handled to about 800 g, regardless of load size.

The usual practice is to collect one, or at most, two probe samples from each load, without regard to sampling location within the load.

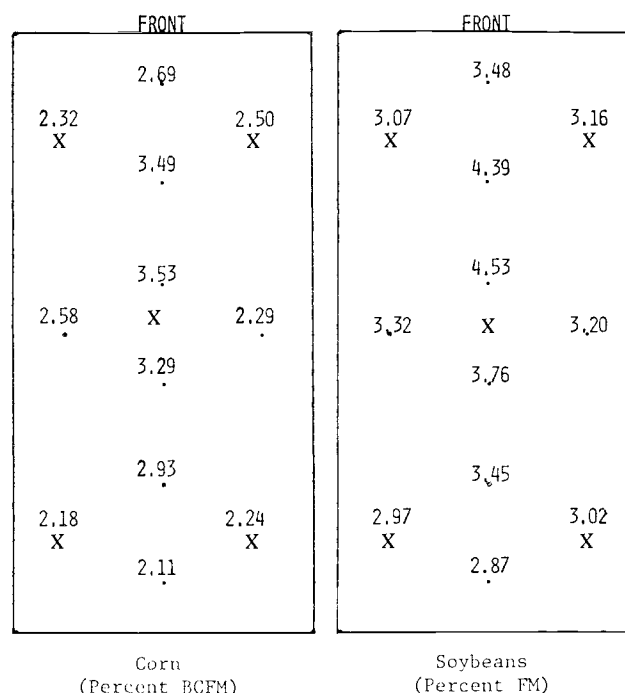
The probe, a device for point-sampling stationary grain lots, was first used in the 1860s (Hoffman and Hill, 1976). The compartmented hand probe, 12 ft long for barges and railcars 6 ft long for trucks, is approved by FGIS for official inspections (USDA, 1983a). Mechanical probes have been accuracy-tested relative to the hand probe (Hurburgh and Bern, 1983). Two types of mechanical probes, gravity-fill and core, are approved for use in Iowa.

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Locations marked X are included in official USDA method.

Fig. 1—Distribution of foreign material in truckloads of corn and soybeans. (After Hurburgh, 1980).

The Hurburgh and Bern probe study also showed a consistent distribution of foreign material within truckloads of corn and soybeans. Foreign material, used generically in reference to the Official corn and soybean Grade factors broken corn-foreign material (BCFM) and foreign material (FM), respectively, varied 1 to 5 percentage points within individual loads as shown in Fig. 1. Sampling locations on the centerline contained substantially more foreign material than locations off the centerline. Corner sampling locations underestimated foreign material content. The consistent distribution suggested that two variables, probing location and number of samples per load, could be adjusted to provide an improved sampling procedure for country elevator use.

The Federal Grain Inspection Service truck-probing regulations include both multiple-probing and probing-location specifications. FGIS regulations require 5 to 9 probings per truck depending on size (USDA, 1983a). However, country elevators have neither the time nor the sample-handling capability to collect 5 or more samples per load.

Foreign material (FM) content is the main criterion for judging sampling methods because foreign material is the most variable of the Official Grade factors. The

majority of FM is fine material which settles out under spouts. Bulky large pieces roll to the edges but generally are less than 0.3% by weight. Hurburgh (1984) measured within-load variability of corn moisture content, test weight, BCFM, large broken kernels, protein content, oil content, and breakage susceptibility. BCFM and moisture were not distributed uniformly throughout loads. BCFM and breakage susceptibility were the most variable within loads; test weight and protein were the least variable.

Foreign material was also the most variable factor in studies of ocean-vessel loading (Hill et al., 1981, 1985) and was the factor most responsible for downgrading U.S. export shipments of corn and soybeans in 1984-1985 (USDA, 1986a, b). Therefore, the probe test study, with its emphasis on foreign material sampling, provided useful data for the design of a country-elevator probing procedure.

The reference method for evaluating truck-probing methods is the pelican. The pelican is an FGIS-approved hand-operated diverter sampler for flowing grain (USDA, 1983b).

## OBJECTIVES

The objectives of this research were to:

1. Design a probe-sampling procedure for country elevators.
2. Test and validate the procedure at an elevator.

## MATERIALS AND METHODS

### Development of the procedure

Data from the Hurburgh and Bern (1983) probe tests was used to develop a probing procedure for country elevator use. The "true" foreign material value for the loads was assumed to be the average of all 12 probing locations (2.68% for corn, 3.44% for soybeans). This assumption was supported by other research where tailgate (pelican) samples were taken along with the 12 probe samples (Hurburgh, 1984). The FGIS 5-probe pattern ("Z") represents the locations marked "x" on Fig. 1. This is the FGIS pattern that would be used on trucks of this size. The "Z"-pattern foreign material average is 0.15 percentage-points lower than the all-12-location averages for both grains.

To estimate the concentration of foreign material at points other than those sampled, the distribution of foreign material was approximated as linear laterally from the longitudinal axis of the loads and as linear longitudinally between points on the centerline. The loci of points of average foreign material concentration were then determined as fractions of width,  $W$ , and length,  $L$ . A band containing all points with  $\pm 0.5$  point of the average was calculated. There was little difference between corn and soybeans in either the position of the average foreign material line or the band width.

Therefore, the probing bands for corn and soybeans were combined, then averaged across the longitudinal centerline for symmetry. The changes arising from symmetry were also small. Fig. 2 shows the final version of the plan, along with the line of average concentration. Probing within the shaded area could be expected to yield samples within  $\pm 0.5$  percentage points of the average FM concentration. Then, the number of probings within the shaded area will control random error which is inversely proportional to the square root of

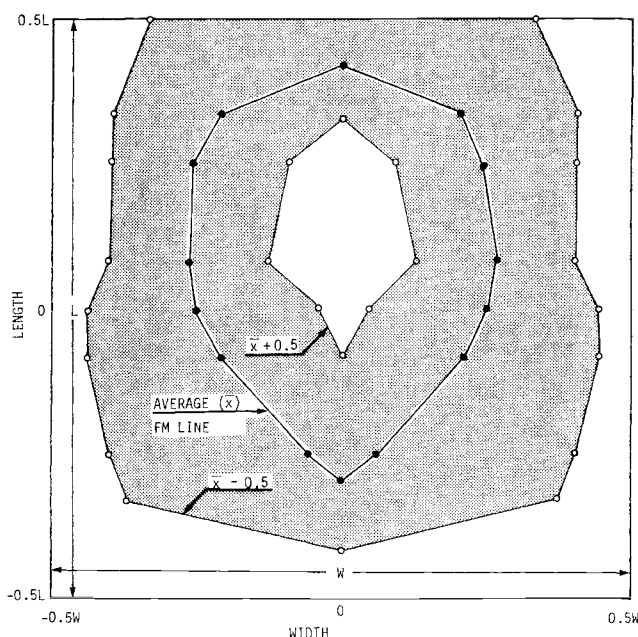


Fig. 2—Truck-sampling locations that contain foreign material within 0.5 percentage point of the load average.

sample numbers. For example, a composite of two probes per load would be expected to contain 70.7% as much random error as one probe per load.

### Sample collection

On October 25, 1982, 38 farmer-delivered loads of freshly harvested corn were sampled both by the cooperating elevator with its gravity-fill mechanical probe and by University personnel with a pelican at the dump it. The first 16 loads were probed once per load in the plan-designated area. The last 22 loads were probed twice per load, again in the designated area. Load sizes ranged from about 4.5 m<sup>3</sup> (125 bu) to more than 28 m<sup>3</sup> (800 bu).

Pelican sampling frequency was increased from two cuts per load to one cut for approximately 1.75 m<sup>3</sup> (50 bu) of grain. To prevent overflowing, the pelican was tilted so that its projected open area to the stream was matched to the operator's strength and the grain flowrate. Each cut collected about 1000 g. The cuts were combined, then the composite was divided as required in a Boerner divider to yield analysis samples of approximately 3000 g. The sample-pairs (probe sample and pelican sample) were taken to the Iowa State University Grain Quality Laboratory, where they were tested for seven quality factors.

Soybean samples, 20 probe-pelican pairs with one probe per load and 20 pairs with two probes per load, were collected on October 3, 1983. The soybean samples were handled in the same manner as the corn samples.

### Laboratory testing

Table 1 provides a summary of the quality tests. Calibrations for the GACIII near-infrared reflectance (NIR) unit were done at Iowa State University.

The order of analyses was test weight, BCFM and large broken (FM and splits for soybeans), oven moisture content, NIR, and breakage susceptibility. In this way, the particle-size integrity of samples was never altered by hand removal of grain. Soybean damage was

TABLE 1. QUALITY TESTS FOR CORN (C) AND SOYBEANS (S).

Test	Replicates per sample	Grain	Instrument	Procedure (reference)
*Moisture, %	3	C	Air-oven, forced convection	Whole-grain heated 72 h at 103 °C (USDA, 1984)
		S		Ground grain heated 1 h at 130 °C (USDA, 1984)
*Test weight, lb/bu	1	C, S	Official test weight apparatus	Quart kettle struck-off level (USDA, 1980a)
*Broken corn-foreign material	1	C	Carter dockage tester	4.8-mm (12/64-in.) round-hole screen, plus handpicking of (USDA, 1980b, c)
Large broken, %	1	C	Carter dockage tester	6.4-mm (16/64-in.) round-hole screen
*Foreign material, %	1	S	Carter dockage tester	3.2-mm (8/64-in.) round-hole screen, plus handpicking of coarse foreign material (USDA, 1980b, d)
*Splits	1	S	Carter dockage tester	4.0-mm x 19.2-mm (10/64-in. x 3/4-in.) slot sieve (USDA, 1980b, d)
*Damage	1	S	Visual selection	Hand sorted from 125-g subportion (USDA, 1980d)
Breakage	1	C	Wisconsin breakage tester	200-250 g, conditioned to 12.8% moisture, 4.8-mm (12/64-in.) round hole screen (Watson and Herum, 1986)
Protein content, %† and oil content, %†	1	C, S	Dickey-john GACIII near-infrared reflectance analyzer	Grinding in Magic Mill III+ flour mill, calibrations to Kjeldahl and Goldfisch methods respectively (AACC, 1983a, b)

\*U.S. grade factors or Official criteria.

†Adjusted to 15.5% moisture (corn) or 13.0% moisture (soybeans).

determined by a designated official grading agency on a Boerner-divided subsample removed after the test weight determination.

The breakage susceptibility tests were run on corn subsamples conditioned by slow, cool-air drying to 12.8% moisture wet basis. The subsamples at their initial moisture content were weighed to the nearest 0.01 g, then dried to the proper weight at 12.8% moisture. In lieu of waiting 72 h for oven test results, initial moisture for conditioning was determined on a Dickey-john GACII moisture meter. Because the meter test did not always agree with the subsequent oven test, the actual conditioned moisture content was later calculated. Studies have shown a 40% change in breakage susceptibility per percentage point of moisture (Paulsen, 1983; Hurburgh, 1983). Therefore, the small differences in conditioned moisture among samples were compensated with the following moisture adjustment formula.

$$B_f = B_c (1.40)^{(M_f - M_c)} \dots \dots \dots [1]$$

where:

$B_f$  = breakage susceptibility at final moisture (12.8%) content, %

$B_c$  = breakage susceptibility at actual conditioned moisture content, %

$M_f$  = final moisture content, % (12.8%)

$M_c$  = actual conditioned moisture content, %

#### Statistical analysis

For each quality factor, the pelican test result was

subtracted from the probe result on a load-by-load basis. The differences were averaged across loads, and a standard deviation of differences was calculated. The average probe-pelican errors and their respective standard deviations were used to check the two assumptions underlying the two-sample plan: (a) that biased locations had been eliminated and (b) that the standard deviation of the two-probe loads relative to the pelican would be 70.7% of that of the one-probe loads. A t-test at the 0.05 probability level was used to compare mean probe-minus-pelican differences by quality factor between procedures. The standard deviation of probe-minus-pelican values for two-probe loads,  $s_{d2}$ , was divided by the standard deviation of probe-minus-pelican values for one-probe loads,  $s_{d1}$ , to form a variability ratio, in theory equal to 0.707.

#### RESULTS AND ANALYSIS

Summaries of the test data are given in Tables 2 and 3. There were no major discrepancies between either probing method and the pelican. The two-probe plan did improve the accuracy of foreign-material and splits determinations in soybeans. For either U.S. grade factors only and/or all factors combined, the two-probe pattern reduced variability, although not by the amount as predicted from statistical theory. The error reduction varied widely by quality factor and grain.

Corn breakage susceptibility had the largest standard deviation of differences between probe and pelican. Sampling problems probably have contributed to the large variations reported in collaborative studies of the Wisconsin breakage tester (Watson and Herum, 1986).

TABLE 2. COMPARISON OF PROBE-SAMPLING METHODS, CORN

Quality factor	One probe per load (16 loads)				Two probes per load (22 loads)				Variability ratio, $s_{d1}/s_{d2}$
	Pelican		Probe minus pelican		Pelican		Probe minus pelican		
	Average	Std. dev.	Average	Std. dev., $s_{d1}$	Average	Std. dev.	Average	Std. dev., $s_{d2}$	
*Moisture, %	20.00	3.17	−0.41†	0.592	18.72	4.47	0.28†	0.577	0.975
*Test weight, lb/bu	53.70	3.13	0.00	0.837	55.00	2.53	−0.20†	0.395	0.472
*Broken corn, foreign material, %	0.59	0.34	0.41†	0.299	0.68	0.39	0.49†	0.238	0.796
Breakage susceptibility, %	13.20	5.40	−1.90†	3.025	12.60	5.27	1.00‡	3.258	1.077
Protein, % basis 15.5% moisture	8.27	0.95	0.12	0.466	7.90	0.76	−0.18‡	0.244	0.524
Oil, % basis 15.5% moisture	3.70	0.31	0.16	0.335	4.10	0.42	0.04	0.283	0.845
Average ratios:									
U.S. Grade factors or Official Criteria									0.748
All factors									0.760

\*U.S. grade factors or Official Criteria

†Different from 0.0 (P= 0.05)

‡Different from one-probe value (P= 0.05)

TABLE 3. COMPARISON OF PROBE-SAMPLING METHODS, SOYBEANS

Quality factor	One probe per load (20 loads)				Two probes per load (20 loads)				Variability ratio, $s_{d1}/s_{d2}$
	Pelican		Probe minus pelican		Pelican		Probe minus pelican		
	Average	Std. dev.	Average	Std. dev., $s_{d1}$	Average	Std. dev.	Average	Std. dev., $s_{d2}$	
*Moisture, %	10.84	1.70	−0.19	0.476	11.00	2.43	−0.27†	0.315	0.662
*Test weight, lb/bu	57.38	0.57	0.31†	0.399	57.13	0.76	0.36†	0.390	0.977
*Foreign material, %	0.59	0.54	0.20†	0.376	0.78	0.50	−0.01‡	0.345	0.918
*Splits, %	1.41	0.91	1.04†	0.677	2.00	1.57	0.77†,‡	0.464	0.685
*Damage, %	0.38	0.17	−0.04	0.295	0.58	0.41	0.09	0.299	1.014
Protein, % basis 13.0% moisture	34.19	0.51	−0.04	0.315	34.76	0.82	0.04	0.390	1.238
Oil, % basis 13% moisture	19.93	0.26	−0.28†	0.236	19.17	0.43	−0.17†,‡	0.213	0.903
Average variability ratios:									
U.S. Grade factors or Official Criteria									0.851
All factors									0.914

\*U.S. Grade factors or Official Criteria

†Different from 0.0 (P= 0.05)

‡Different from one-probe value (P= 0.05)

Large sampling errors for breakage susceptibility have also been reported in other grain-quality studies (Hurburgh and Moechnig, 1984; Hurburgh, 1984). The practical effect of large sampling errors would be trading controversies should breakage susceptibility become a grain-pricing factor, as at least one researcher has proposed (Hill, 1980).

The nutrient measures protein and oil content had smaller standard deviations than the current Official factors. Therefore, sampling for nutrient composition, should this become price-determining, will be no less accurate than accepted for present market factors.

## CONCLUSIONS

A plan for selecting locations to probe-sample wagon and truck loads of grain was designed, then tested at a country elevator in corn and soybeans.

1. The design calls for avoiding center and corner locations within loads and for multiple-sampling of each load.

2. When compared with one probe per load, the collection of two probes per load reduced random sampling error 24% in corn and 8% in soybeans. Statistical theory predicted a 29% reduction. For official grade factors only, random error reductions were 25%

and 15% for corn and soybeans, respectively.

3. There were no large biases between probe samples and pelican samples for either one or two probes per load.

4. Corn breakage susceptibility was the most variable quality characteristic to sample and measure. Protein and oil content in both grains showed the least variability.

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